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Abstract. The high-spin states of the odd-odd ^{110}In nucleus have been investigated in the ^{100}Mo(14N, 4nγ) reaction and observed up to 5.6 MeV excitation energy. An intense $\Delta I = 1$ cascade has been found from 7^- to 14^- and has been interpreted in the frame of the axial rotor + two quasiparticles model including Coriolis interaction.

I. Introduction

Recent studies have begun to explore the high spin structure of doubly odd-transitional nuclei in particular within the Au-Tl region [1,2] and around the shell closure Z = 50 [3,4]. This investigation is a part of a more systematic investigation of odd-odd silver and indium nuclei excited through heavy-ion reactions. The interest of odd-odd nuclei such as indium is the possible existence of a so called "conflicting case" [5] : the quasi-particles that give rise to collective bands in neighbouring odd-A nuclei have opposite behaviours in the framework of the rotor + quasiparticle model. Namely, the $\pi g_{9/2}$ orbital leads to a coupled band structure ($\Delta I = 1$) whereas the $\nu h_{11/2}$ orbital accounts for decoupled bands $\Delta I = 2$. In ^{108}In (as in ^{196,198}Tl), such a conflicting case gives rise to a simple sequence of $\Delta I = 1$ levels interpreted in the frame of the rotor + two quasi-particle model including Coriolis interaction.

2. Experimental procedure and results

The levels of ^{110}In have been excited using the ^{100}Mo(^{14}N, 4nγ)^{110}In reaction. Experiments were carried out by means of the Grenoble ISN cyclotron. The Mo target enriched to 97 % in ^{100}Mo consisted of a 1 mg/cm^2 foil deposited on a lead backing of about 30 mg/cm^2. Two Ge(Li) detectors having an efficiency of 15% and an X-ray intrinsic Ge detector were used in the γ-ray experiments. The γ-ray yield has been measured as a function of bombarding energy within the range 55-75 MeV. The maximum of ^{110}In production occured at 62 MeV. This energy has been selected for all in beam experiments. A single γ-ray spectrum is shown in fig. 1. The main parasitic lines are those of ^{109,110}Cd, ^{109}In and ^{107}Ag.

About 2.10^7 biparametric 2048 x 2048 channel γ-γ coincidence events have been recorded. The time resolution of prompt events was 15 ns. Accidental coincidences (delay time of about 60 ns) as also out of burst coincidences have been simultaneously recorded. No evidence for an isomeric state has been observed.

The angular distributions were measured at five angles ranging from 0° to 90° with respect to the beam direction. The normalization was deduced from spectra recorded by a fixed Ge(Li) detector. The linear polarization of ^{110}In γ-rays was measured using the five germanium detectors Compton polarimeter described in reference 6. The experimental value of the polarization p is deduced from the coincidences scatterer plus horizontal analysers (N_H) and scatterer plus vertical ones (N_V) through the relation :

$$p = \frac{1}{Q(E)} \frac{N_V - N_H}{N_V + N_H}$$

where Q(E) is the polarization sensitivity of the

(x) Present address : I.E.N. Alger, Algeria polarimeter. The A2, A4 and p coefficients extracted from those measurements are listed in table 1. A typical N_V-N_H spectrum showing evidence for the polarization sign is displayed in fig. 2. The electron spectrum of ^{110}In has been measured with the help of the ISN orange spectrometer at Grenoble[12]. The α_K values extracted from this experiment support the previous assignments deduced from angular distributions and polarization measurements. The level scheme deduced from available experimental evidence is given in fig. 3. The ground state has been previously measured to be 7^+ [7]. Above the g. s. and the first positive parity states is observed an intense cascade where states from 7^- to 14^- are connected with $\Delta I = 1$ transitions. The E 1 multipolarity of the 1337 keV transition establishes the positive parity of the cascade starting with spin 12 at 3512 keV.

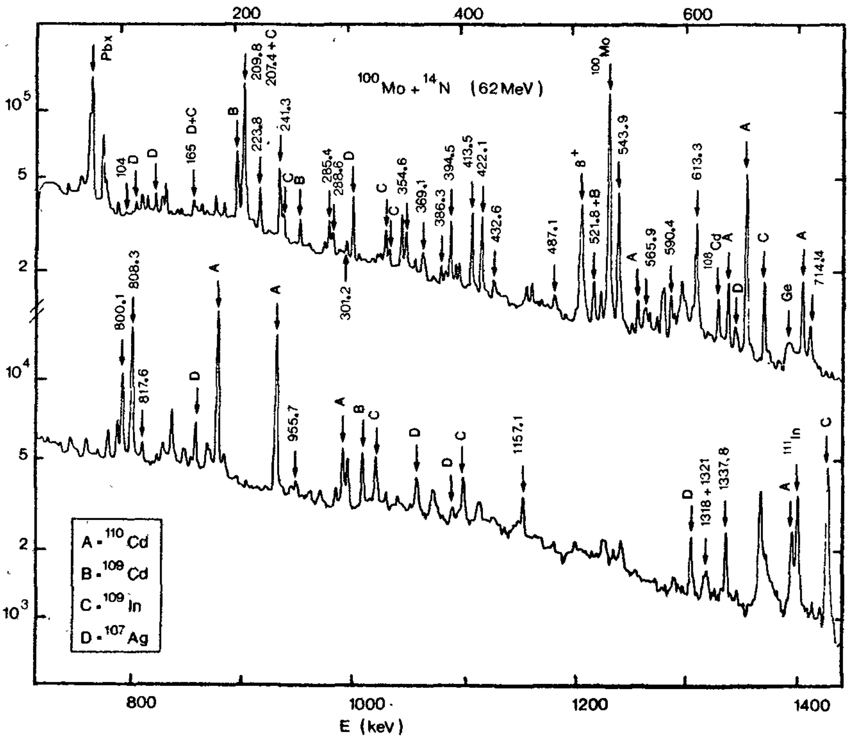

Figure 1 - γ-ray spectrum of the ^{100}Mo(^{14}N, 4nγ) reaction at 62 MeV

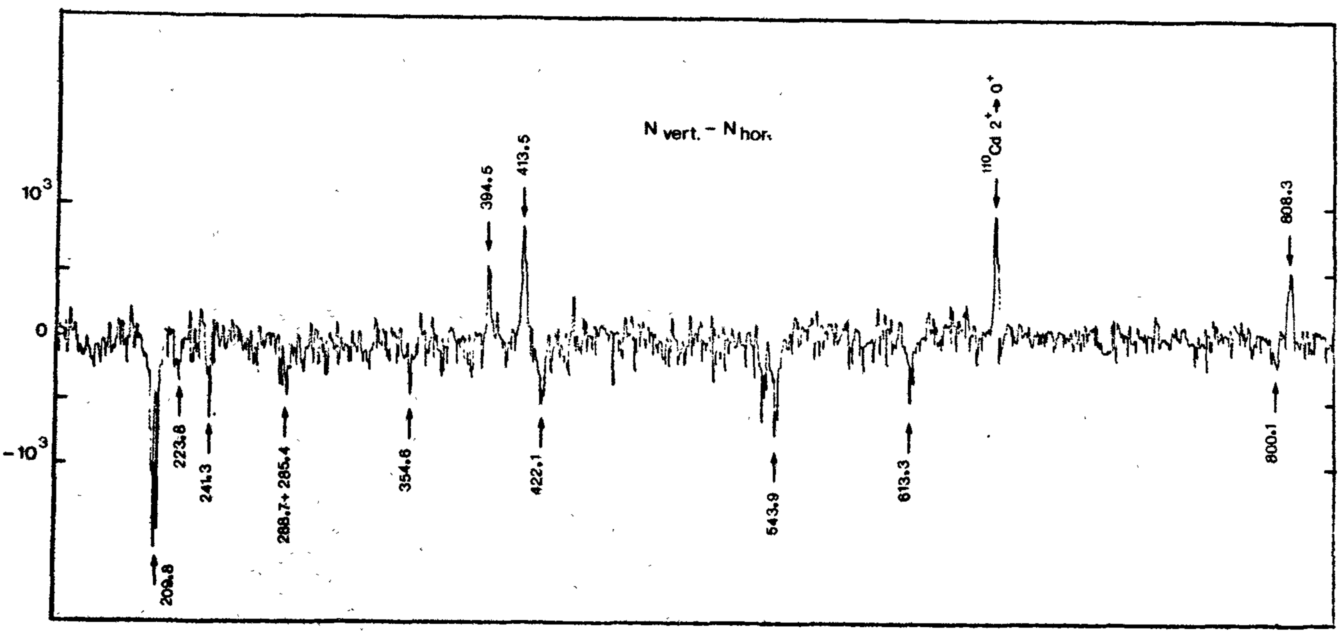

Figure 2 - A typical N_V - N_H γ-ray spectrum. The positive (negative) peaks show positive (negative) linear polarization.

E_γ (keV)	I_γ b)	A_2	A_4	P	Multipolarity
8.2	a)				
104.5	2.5				
165.0	2.6				
207.4	8.0	-0.30(5)	-0.02(5)	-0.23(6)	M1
209.8	100	-0.19(4)	+0.01(4)	-0.32(3)	M1
223.8	11.2	-0.16(5)	+0.05(5)	-0.36(6)	M1
241.3	34.5	-0.14(4)	+0.02(4)	-0.38(4)	M1
285.4	13.8	-0.17(6)	-0.06(6)	-0.4 (1)	M1
288.6	7.2	-0.28(8)	+0.14(7)		M1
301.2	5.8	+0.08(7)	+0.08(7)		
354.6	16.2	-0.20(6)	+0.03(6)	-0.52(9)	M1
363.4	5.0	-0.03(10)			
367	1.5				
369.1	8.4	-0.65(12)	+0.25(7)	-0.34(8)	M1
386.3	7.5				
394.5	26.	-0.20(4)	+0.01(4)	+0.58(9)	E1
413.5	41.	+0.33(3)	+0.06(5)	+0.73(9)	M1
422.1	35.	-0.09(4)	+0.02(4)	-0.32(4)	M1
432.6	6.3	-0.42(10)	+0.14(10)		(M1)
481	2	-0.36(15)			
487.1	5.3	-0.45(9)	+0.30(15)		(M1)
521.8	13.4	+0.20(5)	+0.06(7)	+0.21(16)	
543.9	62.	-0.15(4)	+0.05(4)	-0.38(3)	M1
565.9	4.3				
567.5	2				
590.4	11	-0.32(7)	+0.10(6)		(M1)
609	4				
613.3	52	-0.08(4)	+0.03(4)	-0.25(3)	M1
714.4	13	-0.10(6)	+0.2(1)	-0.74(20)	M1
754.	5	-0.03(10)			
800.1	29	+0.37(3)	+0.05(5)	-0.80(25)	E1
808.3	57	-0.15(4)	+0.03(3)	+0.42(5)	E1
817.6	7				
955.7	3	+0.05(8)			
1035.	3	+0.6(2)			
1157.1	9	+0.33(6)	-0.03(9)		(E2)
1242.	4	-0.3(2)			
1318	2.4				
1321	2.8				
1337.8	6	-0.26(10)	-0.1(1)	+0.9(4)	E1

Table 1 - Energies, intensities, angular distribution coefficients, linear polarization and multipolarity of γ-rays assigned to ^{110}In.
a) This very low energy transition has not been observed with an intrinsic Ge X-detector because of its large conversion coefficient but its existence is required to explain the coincidence results
b) Relative γ-ray intensities at 62 MeV bombarding energy corrected for angular distribution. Energy (intensity) uncertainties are about 0.2 keV (10%) for intense transition ($I_\gamma > 20$) and 0.5 keV (20%) for the other ones.

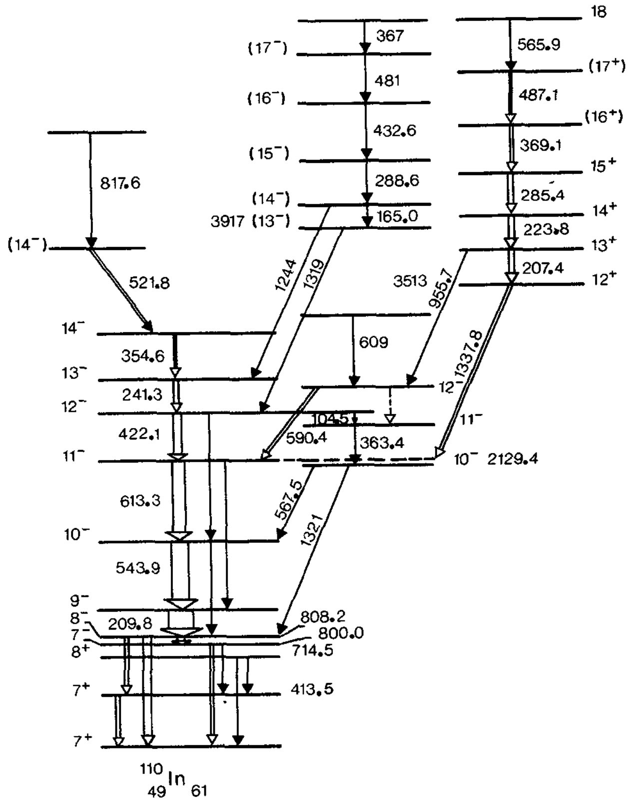

Figure 3 - Level scheme of ^{110}In obtained from this study

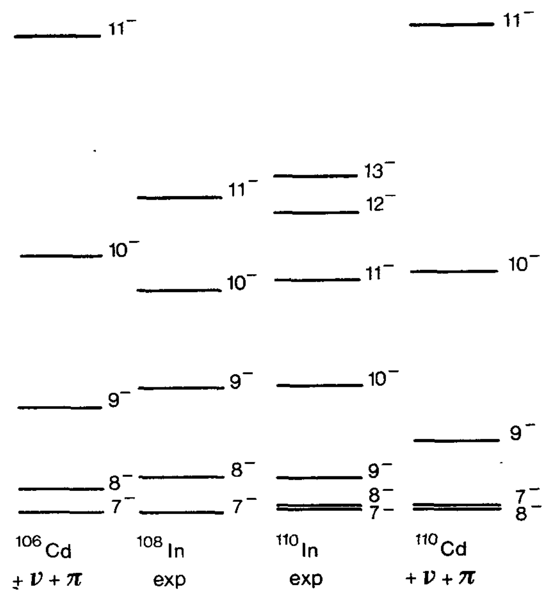

Figure 4 - Experimental negative parity states in ^{108}In and ^{110}In compared with the theoretical ones.

3. Discussion

The more striking feature is the presence of an intense $\Delta I = 1$ cascade of negative parity levels as it has been observed in ^{108}In. Due to the presence of levels with spins higher than 10, this scheme cannot be explained as $\pi g_{9/2} \otimes \nu h_{11/2}$ multiplet states [8]. Potential energy calculations [9] for odd indium isotopes indicate a small prolate equilibrium deformation. Therefore, as in ^{108}In and in odd-odd thallium, we apply the two quasi-particles+axial rotor model including Coriolis interaction. The quasi-particle energies of neutron and proton, the pairing coefficient u_j and the deformation have been extracted from constrained H.F. calculations on ^{106,110}Cd presented in a recent paper [10]. These band mixing calculations have been performed by taking into account all proton and neutron orbitals situated within one MeV on both sides of the Fermi level. The residual interaction between the valence proton and neutron has been neglected in our calculation. Comparison between experiment and theoretical calculations is given in figure 4 for both ^{108}In and ^{110}In. The model accounts for the special nearness of the 7^- and 8^- states in ^{110}In.

The experimental sequence is relatively well reproduced except a slight energy expansion of the calculated level scheme ; it should be noted that no free adjustable parameter is enclosed in our calculations. The inclusion of a variable moment of inertia or the attenuation of the Coriolis interaction should lead to a bunching of the states [11]. The coexistence of E2 and M1 transitions accounts that this sequence looks like a rotational band based on the 8^- level composed predominantly of K = 6, 7, 8 band-mixing arising from $\nu h_{11/2}$ ($\Omega_n = 3/2, 5/2, 7/2$) $\otimes$ $\pi g_{9/2}$ ($\Omega_p = 9/2$) states. The positive parity band built on the 12^+ state located at 3512 keV cannot be explained in this pure two-quasi particles + rotor model.

In conclusion the Coriolis interaction appears to be dominant also in doubly odd transitional nuclei in presence of high-j unique parity orbital, on the assumption that the proton-neutron interaction is weak.

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